Cognitive-communication disorder following right hemisphere damage: Narrative production

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ABSTRACT

Background: Cognitive-communication disorder (CCD) results from the association of language and cognition impairment that may follow right hemisphere (RH) damage and impair the quality of life of affected persons.
Objective: We studied a set of 1,625 narratives produced by a cohort of 125 individuals (50 with a single right vascular lesion in the MCA territory and 75 cognitively healthy controls) using a task of picture-based discourse production. Discourse production was analyzed in its macro-and microlinguistic aspects to characterize better the linguistic mechanisms underlying RH patients' performance.
Results: The RH group produced more words and elocutions than controls, with a lower rate of informational content and a higher percentage of global coherence errors (all p-values <0.0001).
Conclusion: Individuals with RH lesions showed formal lexical and syntactic aspects of discourse mostly preserved. Alterations in the macrostructure of discourse prevailed over microstructural alterations in our sample, according to most literature studies. The group of individuals with RH lesions produced narratives containing more words and utterances, with a lesser degree of lexical information and more global coherence errors.

1. Introduction

Language alterations exhibited by individuals with brain damage to the right hemisphere (RH) are part of an umbrella term known as "cognitive-communication disorder" (CCD), a condition that harms the person's social interaction, professional performance, and quality of life. The term CCD encompasses a series of language comprehension and production difficulties associated with deficits in cognitive domains such as attention, executive functions, working memory that lead to diminished effectiveness and efficiency in communication [1].

Language impairment following RH lesions tends to be pervasive, which often leads to an impression of an "inadequacy" in speech, as the patient seems to lose the ability to communicate appropriately without being aphasic, due to discursive and pragmatic disturbances. Patients with RH lesions are less efficient than the general population in their communication, which their listeners often consider disorganized, tangential, verbose, and lacking informational content [2]. These patients also present difficulties comprehending figurative language or making inferences, among other deficits. As a result, their communicative interaction is highly impaired, negatively impacting social interactions and professional performance [3].

Previous reports on individuals with focal RH lesion (from vascular or traumatic etiology) have revealed a gamma of alterations that includes: a) deficits in prosody, the suprasegmental aspects of speech such as modulation of voice intensity, pauses, and intonation; b) deficits in lexico-semantic processing: comprehension of metaphors, production of semantic paraphasias; c) deficits in pragmatic abilities: difficulties in the interpretation of indirect acts of speech, comprehension of irony, sarcasm, and humor; d) deficits in discursive production: disorganization, lower content of information, tendency to produce incoherent speech (with erroneous or absent anaphoric references), digression, and lack of thematic progression; e) deficits in discursive reception: making inferences, interpret implicit information, grasping the central idea or moral of a story, provide a title or a sentence to summarize the central theme of a narrative [4]. A recent study showed that individuals with RH lesion produce more errors in using personal and demonstrative pronouns as cohesive ties [5].

Although communicative alterations have long been recognized in individuals with RH lesions [6], their exact subjacent mechanism is not well understood. Impairment in discourse abilities has been attributed to attentional, executive, and memory deficits [7], apart from a specific contribution of the RH in language processing. A narrative (story)

revolves around characters who have intentions or goals and events by a temporal or causal connection, as proposed by Mar [8]. The comprehension and production of narratives require that the individual can attribute mental states, emotions, intentions, and goals to the characters of a story as autonomous agents on a chain of events, which constitutes the ability named as Theory of mind (ToM). Therefore, ToM impairment has also been hypothesized to play a role in discourse alterations in patients with RH lesions [9,10].

Regarding anatomical correlates, there is evidence that narrative comprehension depends upon the right frontal and temporal lobes, especially the inferior frontal [11] and middle temporal gyri [8]. A meta-analysis of 12 PET and fMRI studies revealed the participation of four major regions of the right hemisphere in the comprehension of narratives (in association with their homotopic areas in the left hemisphere): anterior temporal lobes (for integration of semantic information), medial parietal cortex (for establishing and updating situation models), dorsomedial prefrontal cortex (for inference-making) and the temporoparietal junction (for attributing thoughts to characters in the story) [12]. Activation of the right frontal /prefrontal areas is necessary to produce coherent narratives [8,13]. Schneider et al. [14]. have recently reported a positive correlation between gray matter intensity in the right precentral gyrus/*pars opercularis* and narrative cohesion, whereas a higher score in the production of discourse macropropositions was positively correlated with gray matter density in the right primary motor area and insula.

According to Minga et al. [7], by 2019, there were only 25 research studies on the topic of discourse production, measuring more than 35 different aspects of production (cohesion, coherence, pragmatics, and others) and using diverse types of discursive production, such as narrative, description, storytelling, procedural discourse, among others. This data gives us a measure of the magnitude of the endeavor we face when addressing this topic.

We aimed to study a cohort of subjects with a single right vascular lesion in the middle cerebral artery (MCA) territory using a task of picture-based discourse production. Discourse production was analyzed in its macro- and microlinguistic aspects in an attempt to provide a better comprehension of the linguistic mechanisms underlying RH patients' performance. We also aimed to obtain data which will help to guide rehabilitation efforts in this population.

2. Material and methods

Patients were recruited from a Neurology Emergency Service linked to a university hospital, where one of the researchers (A.F.R.) preselected those who had been diagnosed as having unilateral damage centered on the RH as defined by a neurologist after clinical examination and neuroimaging study. Those patients were referred to the neurology outpatient service of the same university hospital after discharge, where they were evaluated for inclusion and exclusion criteria as follows:

- Inclusion criteria: individuals included in this study were aged 18 years and above, right-handed as determined by the Edinburgh Handedness Inventory [15], native Brazilian Portuguese speakers, and had a formal education level equal to or higher than four years. In addition, subjects presented normal scores according to age and years of education for the Brazilian population in the following tests: Mini-Mental State Examination (MMSE) [16,17], Boston Naming Test (BNT) [18] - reduced version (15 items), animal fluency [19], and Clock Drawing Test (CDT) [20]. Those tests were applied to ensure that the individuals enrolled in the RH group did not have significant deficits regarding global cognition, lexical access, executive functions, or visuospatial abilities that could hamper their performance in the narrative task. Also, subjects were allowed to obtain a maximum score of seven on the Hamilton Scale - 21 items (Ham-D 21) [21] to rule out depressive symptoms that might impair cognitive performance. Individuals included in the right hemisphere (RH) lesion group presented with a single vascular cortical lesion in the right middle cerebral artery (rMCA)

territory, as confirmed by neuroimaging study (computerized tomography - CT or magnetic resonance imaging - MRI). All patients were evaluated at the chronic stage (mean time post-stroke: 16.4 ± 19.3 months).

- Exclusion criteria: for the control group, we excluded individuals with a history or evidence of previous or current neurological diseases; history or evidence of psychiatric illness; chronic use of alcohol or illicit drugs; use of medications in doses that could impair cognition; non-correctable alteration of hearing and visual perception. The patient group was composed following the same criteria, except for the presence of the single vascular lesion in the right MCA artery territory. Additionally, in order to exclude alterations that could compromise the ability of visual perception, all subjects were evaluated using the Cancellation Test (CT) [22].

One hundred and eighty-eight patients with RH lesions were preselected. Fifty-three individuals were excluded due to the presence of multiple or subcortical lesions; 28 did not agree to participate in the study; 16 showed perceptual changes (hemianopia or visual neglect), nine had depressive symptoms; 11 failed the animal fluency test; 21 failed the CDT, and 32 used of medications that might impair cognitive performance. For the control group, 130 subjects were preselected. We excluded 22 subjects with less than four years of schooling, 11 left-handed, and six who had evidence of neurological or psychiatric diseases (depression, history of brain tumor). Also, 16 individuals were excluded for failing the cognitive screening tests (four failed the animal fluency test, and 12 failed the CDT).

Our final sample was composed of: (a) 50 individuals with a single lesion in the RH (25 males and 25 females) with a mean age of 58.1 years (± 12.0) and mean education of 8.9 years (± 3.2) (b) 75 cognitively normal individuals from the same community, matched for age and educational level to the patient group (35 males and 40 females), with a mean age of 60.3 years (± 8.5) and mean education of 9.6 years (± 4.2). This study was approved by the local Research Ethics Committee and was performed following the Helsinki Declaration as revised in 1989. All participants gave their informed consent before enrollment in the study.

2.1. Language evaluation

All individuals were asked to produce oral narratives from 13 sets of pictures in black and white with homogeneous tracing containing a stimulus picture and a response picture originally designed for the realization of visual inferences [23]. Patients were asked to tell a story based on the situation pictured in each stimulus-response pair of images (e.g., "The boy has a toothache (stimulus); he is going to the dentist (response)"; "The cop gave a traffic ticket to the person who I think was not wearing his seatbelt (stimulus); here he is putting on his seatbelt (response)" - please refer to Appendix A for the correspondent images). The instructions were given at the beginning of the task as follows: "I am going to show you a picture and you are going to tell me what is happening in there; then, you will look to the next picture and tell me how the story ends: what did the person(s) do next? There are thirteen sets of pictures and you will do the same for each one." Each set of pictures was presented separately; the stimulus and response pictures remained side by side, at sight, until the individual finished the story. The examiner then proceeded to the following set of pictures, removing the previous set from the table.

The situations pictured in each set of stimulus/response figures varied slightly regarding the number of elements (such as the number of persons in the scene or the number of ambiance details), which was reflected in the mean number of words produced in each narrative (Appendix C). Oral narratives were recorded using a Digital Sony ICD P630 mini recorder and transcribed verbatim for analysis. There was no time limit for responses. The total time required to complete each narrative was around 15–30 s, and each individual completed the whole set of narratives in approximately ten minutes (including the time spent providing the instructions and answering any examinee's questions

about procedures). Transcriptions were made manually by one of the authors (A.F.R.), who is a speech pathologist with expertise in language disturbances and neurolinguistics. The transcription process followed the guidelines from the Project for the Study of the Cultured Urban Linguistic Norms in São Paulo [24].

2.2. Discourse analysis

Text structure was analyzed regarding the microlinguistic (lexicon, morphology, syntax) and macrolinguistic (discourse coherence, pragmatic) levels according to the criteria proposed by Marini [25] (for details, see Appendix B). The microlinguistic level is composed of the assessment of: a) discourse productivity (number of well-formed words, complete utterances, and the mean length of utterance - number of valid words divided by the number of valid utterances); b) lexical processing (production of semantic paraphasias or paragrammatic errors indicative of semantic failure or difficulties in morphemes placement and use of function words, such as prepositions or conjunctions); syntactic processing - the proportion of well-formed sentences containing all arguments required by a word (sentence completeness) and sentence complexity measured by the proportion of sentences containing independent and dependent clauses. The macrolinguistic level includes the analysis of: a) the informative content - the proportion of well-formed, non-repeated, and non-ambiguous words in the story (i.e., the use of accurate words) and the number of central ideas (thematic units) conveyed by the individual; b) textual organization - the ability to stick to a coherent narrative without tangential, digressive, or inappropriate utterances. Considering that each participant of the study performed 13 narratives, we were able to collect and analyze a total of 1625 narratives.

2.3. Statistical analysis

Demographical and clinical variables (from tests related to the inclusion/exclusion criteria) and performance in linguistic aspects of discourse were analyzed using Student's *t*-test for independent samples. A multivariate analysis (MANOVA) with the lesion site as a between-subject factor and linguistic aspects as a within-subject factor was employed to analyze performance in the narrative production. Linguistic aspects comprised a set of 10 measures (number of words, number of utterances, mean length of utterance, percentage of semantic paraphasias, percentage of paragrammatic errors, percentage of complete sentences, percentage of complex sentences, percentage of lexical information, percentage of global coherence errors, number of thematic units). For these analyses, patients were divided into three subgroups, according to the lesion site: a) anterior (frontal - 10 patients); b) posterior (temporal, parietal and temporoparietal - 16 patients); c) anteroposterior (frontotemporal, frontoparietal and frontotemporoparietal - 24 patients). Anterior lesions were located in the frontal lobe exclusively, i.e., rostrally to the central sulcus and medially to the Sylvian fissure; posterior lesions affected the temporal and parietal lobes, or both, i.e., were located ventrally to the central sulcus and inferiorly to the Sylvian fissure; anteroposterior lesions affected the entire territory of the MCA, thus including frontoparietal, frontotemporal and fronto-temporoparietal lesions. Occipital lesions, i.e., those located caudally to the parieto-occipital sulcus, were excluded. Lesion sites were determined from visual inspection of CT / MRI studies by M.R., a neurologist, without previous knowledge of the patients' clinical data. P-values of less than 0.005 (after Bonferroni's correction) were considered significant for all analyses.

3. Results

Demographic and clinical data for the control and RH groups are displayed in Table 1. Both groups were similar regarding age, education, and sex distribution. The RH group performed poorer than controls in

Table 1
Demographic and clinical data of the sample.

Variable	Controls ($N = 75$)	RH lesion ($N = 50$)	p (two-tailed)
Age	60.3 (8.5)	58.1 (12.0)	0.261
Educational Level	9.6 (4.2)	8.9 (3.2)	0.332
Sex* Male	35	25	0.855
Female	40	25	
MMSE	28.1 (1.6)	27 (1.9)	< 0.001
Animal fluency	18.3 (3.3)	15 (2.3)	< 0.0001
BNT	14.3 (0.4)	13.5 (1.2)	< 0.001
CDT	9.7 (0.6)	8.6 (0.8)	< 0.0001
Ham- D21	0.4 (0.9)	3.4 (2.0)	< 0.0001

Results are displayed as Mean (SD). MMSE= Mini-Mental State Examination; BNT= Boston Naming Test; CDT = Clock Drawing Test; Ham-D21= Hamilton Depression Rating Scale-21 items. *Chi-squared test.

the cognitive screening tests, although in the normal range according to age and years of education. The mean values for each group on micro- and macrolinguistic measures are shown in Table 2.

The RH group produced more words and utterances than controls; in addition, the RH group showed a lower rate of informational content and a higher percentage of global coherence errors. There were no differences between the control and RH groups in the mean length of utterances,% of semantic paraphasias,% of paragrammatic errors,% of sentence completude and complexity, and the number of thematic units. There were no intra-group differences in any linguistic measure when patients were classified according to lesion sites (anterior, posterior, or anteroposterior) in the RH group (Table 3).

4. Discussion

Communication disorders due to lesions in the RH may be subtle, albeit pervasive, and lead to difficulties in social interaction. Discursive abilities are dependent on a high-complex linguistic-cognitive interaction, which is still far from being adequately understood. In this study, we aimed to examine the discourse abilities of individuals with vascular RH lesions using a narrative task.

When asked to produce a narrative based on a couple of figures representing a situation (e.g., a boy picking flowers) and its development (e.g., he gives them to his mother), patients with RH lesion showed different performance than that of controls regarding microlinguistic (related to phonology and syntax) and macrolinguistic aspects (related to discourse and pragmatics).

The RH group, as a whole, albeit producing more words and utterances, produced less informational content; they also produced more

Table 2
Performance of control and RH groups in each linguistic aspect of discourse.

Variable	Controls ($N = 75$)	RH lesion ($N = 50$)	t	p (two-tailed)
Microlinguistic aspects				
Words	245.4 (87.9)	321.6 (56.2)	−5.835	<0.0001
Utterances	53.4 (16.7)	72.3 (11.6)	−6.798	<0.0001
MLU	4.5 (0.8)	4.5 (0.6)	0.604	0.547
% semantic paraphasias	0.02 (0.1)	0.1 (0.2)	−2.153	0.036
% paragrammatic errors	0.04 (0.1)	0.08 (0.1)	−1.418	0.160
% sentence completeness	43.9 (14.0)	38.4 (11.7)	2.339	0.021
% sentence complexity	5.3 (4.5)	4.2 (3.4)	1.573	0.118
Macrolinguistic aspects				
% lexical information	49.3 (16.5)	31.8 (12.9)	6.266	<0.0001
% global coherence errors	45.4 (16.3)	65.2 (12.3	−7.152	<0.0001
Thematic units	18.5 (5.2)	18.0 (6.2)	0.385	0.701

Data displayed as Mean (SD). MLU: mean length of utterance.

Table 3
Multivariate analysis (MANOVA) of linguistic performance for RH groups according to lesion site.

Variable	Anterior (N = 10)	Posterior (N = 16)	Ant-post (N = 22)	F	P (two-tailed)
Microlinguistic aspects					
Words	338.2 (62.0)	316.6 (49.1)	317.7 (59.5)	0.539	0.587
Utterances	75.8 (12.6)	71.6 (9.8)	71.1 (12.4)	0.584	0.562
MLU	4.4 (0.40)	4.4 (0.7)	4.5 (0.7)	0.018	0.982
% semantic paraphasias	0.0 (0.0)	0.2 (0.3)	0.0 (0.1)	2.325	0.109
% paragrammatic errors	0.0 (0.0)	0.1 (0.2)	0.0 (0.1)	3.104	0.055
% sentence completeness	39.5 (12.4)	35.3 (11.2)	40.2 (11.9)	0.842	0.437
% sentence complexity	5.5 (5.1)	3.6 (2.1)	4.0 (3.2)	0.974	0.385
Macrolinguistic aspects					
% lexical information	31.0 (12.5)	29.5 (11.6)	35.4 (12.2)	1.206	0.309
% global coherence errors	51.6 (16.6)	49.5 (14.6)	45.4 (14.6)	0.695	0.504
Thematic units	16.9 (5.4)	16.7 (6.7)	19.6 (6.1)	1.278	0.288

Data displayed as Mean (SD); RH=right hemisphere; Ant-post=Anteroposterior; MLU=mean length of utterance.

tangential/incongruent utterances than controls. Data reported in the literature regarding microlinguistic aspects of discourse is conflicting: subjects with RH lesions may produce narratives with as many or more words than controls [26,27]. Our study reproduced these findings in that RH patients produced more words and utterances (leading to similar MLUs) than controls.

Most studies report that narratives produced by individuals with RH lesion tend to be simpler regarding syntactic structure. However, we could not replicate the findings of fewer complex propositions (as measured by sentence completeness and complexity) previously reported by other authors [6,25,28], and in that particular aspect, our results are similar to those published by Marini et al. [27]. It must be noted that we observed a trend to statistical significance in our results for sentence completeness that did not survive Bonferroni's correction. We believe that this is a point of controversy that deserves further exploration in future studies.

The literature has extensively reported aspects of discourse production concerning global productivity, content, and global coherence [7, 29]. Individuals with RH lesions are known to produce less informative narratives, as measured by low complexity in sentence production (although the latter is, actually, a microlinguistic aspect considered as pertaining to macrostructure in some studies) [6,30] and exclusion of main concepts [28] or core propositions [6]. In our study, the RH group showed a lower percentage of lexical information (indicating lower and less relevant content by number of words) and a higher percentage of global coherence errors (indicating the presence of tangential and non-pertinent utterances); these findings match those reported by other authors [25,27,31]. Contrary to many previous reports, individuals with RH damage could adequately report the main concepts (thematic units) [14,26,27,30]. Main concepts or core propositions are pieces of information that are expected to be delivered and are determined, for instance, by their consistent presence in the narratives of the majority of controls [26].

We were not able to find any differences in our analysis of the linguistic performance of individuals with RH lesion according to lesion site, which was an unsatisfactory result, but in line with those reported by Marini et al. [25,27]. Functional neuroimaging studies have demonstrated that the RH contributes to language processing in situations of increased demand on semantic selection among alternatives (e.

g., to resolve discourse ambiguities) [32]. Lesions in the RH produce impairment at the lexico-semantic level both in comprehension (right inferior frontal gyrus and insula) [33] and production: patients with RH lesions have difficulties in discriminating polysemic words (i.e., words that have multiple potential meanings) [34] and often activate low probability semantic relations in speech production [4].

Although the influence of the RH in lexico-semantic processes is thought to derive mainly from attentional and working memory areas, a meta-analysis by Vigneau et al. [35] reported RH activation in homotopic regions to LH activation for phonological, lexico-semantic, and sentence or text processing, namely the precentral gyrus, inferior frontal gyrus (IFG), anterior insula, and temporal lobe. These findings support the current view of a strong interhemispheric dependency for language processing [36]. However, patterns of unilateral activation provide more robust evidence regarding the role of the RH in language processing. In the meta-analysis mentioned above, unilateral RH activation was found in the frontal and insular regions in tasks related to auditory selective attention, and in temporal regions for sentence/ text comprehension requiring integration and contextualization of information [35] The right posterior parietal lobe has been implicated in coarse coding deficits, which refer to the impairment in activating and maintaining distant meanings or features of words. Such deficit could be linked to difficulties in comprehending implicit information in narratives [37].

Discursive abilities are considered as a point of intersection between language and other cognitive domains [38], as they require the engagement of attention, working memory, executive functions, and social cognition [7]. In this aspect, we must note that the RH group indeed performed worse (although within the normal range) than controls in tasks of global cognition, executive function, visuospatial function, and naming.

In conclusion, the main findings of our study corroborate the idea that the formal lexical and syntactic aspects are mostly preserved in individuals with RH lesions. In line with most literature studies, alterations in the macrostructure of discourse prevailed over microstructural alterations in our sample. We interpret these findings mainly based on two hypotheses concerning RH participation in discursive abilities: the "suppression deficit hypothesis" and the "social cognition deficit hypothesis". The "suppression deficit hypothesis" states that when faced with multiple possibilities of semantic interpretation (e.g., *bank* of a river x *bank* as a financial institution), the RH plays a pivotal role in suppressing those incompatible or inappropriate to the context. Thus, RH damage would delay or even impede this narrowing of competing interpretations, leading to failures in discourse production and comprehension. The "social cognition deficit hypothesis" stresses the importance of reasoning based on ToM, which accounts for our ability to understand our own and others' mental states (thoughts, feelings, intentions, and beliefs). ToM is an essential element in conversational and narrative production, as well as in inference-making [39]. However, it must be noted that these theoretical approaches (including the mentioned above "coarse coding deficit hypothesis") are complementary in that they account for different levels of a highly complex linguistic ability such as discourse processing.

Our study has limitations: studies based on brain lesion analysis are always imprecise by their very nature, leading to a wide range of clinical findings that hampers the emergence of a homogeneous pattern, particularly in the case of large cortical lesions. We tried to overcome this limitation by focusing on three lesion subtypes, but the smaller number of subjects in each subgroup probably contributed to our failure in demonstrating the effect of lesion site on the patients' linguistic performance. Alternative explanations for our lack of results in this regard are (a) we did not perform any measure of brain lesion parameters (such as volumetry or voxel-based morphometry) that would allow a more precise clinical-anatomical correlation; (b) patients were examined at different times post-stroke, and, therefore, were at different stages of recovery depending on factors such as their age, sex, size of the lesion, and other predictors of stroke recovery [40]

As a general rule, studies focusing on narrative abilities in RH patients use a single-story, be it in the form of one (the Cookie Theft Picture) or multiple scenes (the Cowboy Story, the Cinderella story). We believe that the use of 13 sets of pictures representing a diversity of situations provided a more thorough assessment of subjects' abilities to perceive, interpret and organize narratives representing several different scenarios (performance of daily activities, problem-solving, interpretation of emotional content). That also allowed us to analyze 1625 narratives, which we consider the greater strength of our work.

CCD is currently recognized as a syndrome that requires as much attention and rehabilitation efforts as aphasia to minimize the impact of communication deficits on the quality of life of people with RH damage [41]. At present, there is a paucity of evidence to guide rehabilitation planning for people with CCD due to RH lesions, which is partly a consequence of the lack of information on the precise patterns of disabilities exhibited by these patients. Therefore, we believe that our data may contribute to the clinical characterization of language impairment due to RH infarcts in MCA territory, by means of the assessment and correct identification of deficits in this population. Also, these data may provide better empirical grounds for rehabilitation planning focused on the various deficiencies that may occur in this population.

Funding

Appendix A. - Examples of the set of figures (stimulus-response) used to elicit oral narratives in the study [23] with transcriptions from the narratives produced by two patients and a control
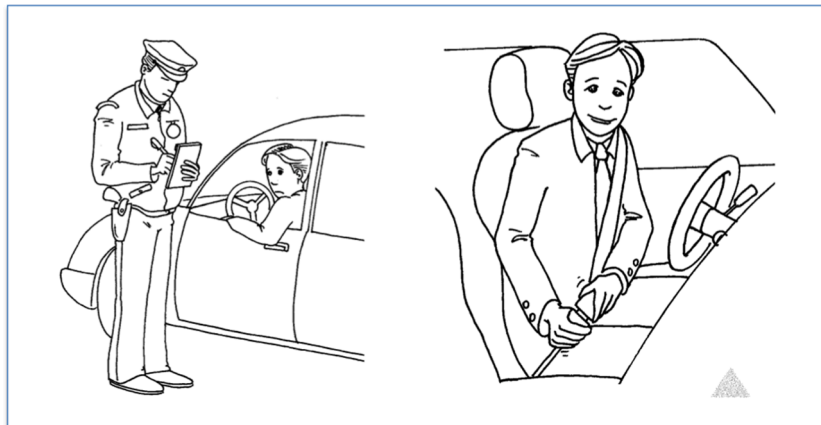

Example 1
Patient 1: "It seems to me that the child has a toothache and the mother is helping. Here the dentist is touching his mouth''
Patient 2: ``Here the boy is crying and the mother is going to comfort him, to check what happened… after… or it could have been before… the boy was… oh, no… he has a toothache… he's crying because he has a toothache and needs to go to the dentist''
Control: "The boy has a toothache… he is going to the dentist''

Example 2
Patient 1: "He's giving a ticket here, right?…he didn't obey the order to fasten his seat belt… and then he got all messed up…"
Patient 2: "The man inside the car must be getting a ticket from the policeman… because he did something wrong… let me think… and look… did he put on the seat belt wrong?''
Control: "The cop gave a traffic ticket to the person who I think was not wearing his seatbelt…here he is putting on his seatbelt"

Appendix B. Micro- and macrolinguistic features used in the analysis of discourse production (based on [20])

Microlinguistic features	
a) Productivity	
Words	- well-formed words (excluding phonemic paraphasias and phonetic errors)
Utterance	- a sequence of words that represent a complete thought, defined by acoustic (presence of pauses), semantic (propositional), and grammatical
Mean length of utterance	(grammatically complete sentence) criteria
(MLU)	- total number of well-formed words divided by the number of utterances
b) Lexical processing	
% Semanrtic paraphasias	- number of substitutions of a target word with another word (semantically related or not) divided by the number of well-formed words and
% Paragrammatic errors	multiplied by 100
	- number of substitutions of bound morphemes or function words divided by the number of well-formed words and multiplied by 100
c) Syntactic processing	
% Syntactic completeness	- number of sentences containing all arguments required by a word (with no omissions of morphosyntactic information or substitutions of
% Sentence complexity	morphemes) divided by the number of utterances and multiplied by 100
	- number of sentences containing at least one independent clause and at least one or more dependent clauses divided by the number of utterances
	and multiplied by 100

Macrolinguistic analysis	
a) Informative content	
% Lexical informativeness	- number of well-formed words also grammatically and pragmatically accurate (excluding paraphasias, paragrammatic errors, ambiguous, repeated
Thematic units	and tangential utterances) divided by the total number of words and multiplied by 100
	- number of propositions containing the principal ideas which are considered critical for the understanding of the narrative (for this study, we used
	the units defined by Obler et al. (1985):
b) Textual organization	
% Global coherence errors	- number of tangential, incongruent, repeated or filling utterances divided by the total number of utterances and multiplied by 100

Appendix C. Mean number of words for each narrative by diagnostic group

Set of figures	Controls (N = 75)	RH lesion (N = 50)	p (two-tailed)
1	20.0 (14.3)	26.7 (13.2)	0.009
2	22.3 (13.8)	31.8 (11.3)	< 0.001
3	21.7 (15.1)	28.1 (9.0)	0.003
4	12.9 (7.9)	16.9 (6.8)	0.002
5	19.1 (14.5)	25.1 (9.3)	0.006
6	15.5 (9.0)	24.3 (10.7)	<0.0001
7	20.9 (11.3)	35.5 (10.8)	<0.0001
8	27.7 (12.7)	30.1 (13.2)	0.304
9	14.7 (9.2)	18.8 (7.5)	0.009
10	14.0 (7.3)	20.8 (7.0)	<0.0001
11	10.9 (4.8)	16.1 (6.1)	<0.0001
12	21.8 (14.4)	28.7 (11.5)	0.005
13	21.7 (15.1)	28.1 (9.0)	0.008

Data displayed as Mean (SD)

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